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# DENSE CLUSTERS OF RAW SEWAGE LOCATIONS ON MINNA NEIGHBOURHOOD GIS MAPS ARE POINTERS TO VERITABLE URBAN DECAY AND MOSQUITO-BREEDING GROUNDS

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## ABSTRACT

**Background**: The lack of comprehensive baseline data on raw sewage pollution in Minna, Nigeria's Niger State capital, represents a significant gap in public health information. This deficiency necessitates a systematic study to establish a database documenting sewage pollution patterns in Minna's urban environment. **Aim**: To employ georeferencing tools and descriptive observations for identifying and mapping potential mosquito breeding sites related to sewage discharge within Minna's built-up areas and to develop an interactive Geographic Information System (GIS) map as an environmental audit tool for public health officials. **Methods**: The study area was divided into five sectors: Greater Bosso, Minna Central, Greater Maitumbi, Tunga, and Greater Chanchaga. Following initial site familiarization and GIS equipment testing, systematic surveys were conducted. Field teams documented locations of household sewage discharge points, collecting geographic coordinates, temporal data (date, time, weather conditions), and site characteristics. Each identified location was photographed and recorded in standardized data sheets, including household information where available. **Results**: Using ArcGIS®10.8 software, comprehensive sewage pollution layers were created for each sector by integrating collected field data with Minna's township built-up and settlement shapefiles. The mapping revealed distinct pollution patterns and clusters across different neighborhoods. **Discussion**: Analysis of the spatial distribution showed a clear correlation between socioeconomic status and sewage management practices, with higher concentrations of improper sewage discharge in low-income areas. **Conclusions**: This database serves as a valuable resource for public health interventions targeting mosquito breeding grounds. Regular monitoring through periodic sewage pollution audits and expanded geographical coverage is recommended for improved urban health management.

**Keywords**: *Sewage-pollution; cesspit; georeferencing; GIS; sanitation*

## 1. INTRODUCTION

The result of the limited-extent pilot study of 2012 (Jonah *et al.*, 2015) to determine the spatial spread of raw sewage discharge over the built-up area of Minna was significant in its novelty because raw sewage discharge points are veritable mosquito breeding sites in the urban area. It is known that mosquitoes are active vector parasites that transmit malarial disease.

The term “sewage” describes raw sewage, sewage sludge, or septic tank waste. Raw sewage is mainly water containing excrement, industrial release, and debris such as sanitary towels, condoms, and plastic. Excrement is the major source of harmful microorganisms, including bacteria, viruses, and parasites. It is also water-carried waste, in solution or suspension, that is intended to be removed from a community. It is more than 99% water and is characterized by

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volume or rate of flow, physical condition, chemical constituents, and the bacteriological organisms that it contains. Sewage treatment reduces the water content and removes debris but does not kill or remove all the microorganisms (www.hss.delaware.gov).

The aim of this study is principally the employment of the tools of georeferencing and descriptive observations to identify locations within the built-up areal extent of Minna that are considered veritable mosquito breeding sites whilst further employing the route of the Geographic Information System (GIS) to create an interactive map of Minna encapsulating this endeavor such that this map becomes an environmental audit mechanism tool in the hands of public health inspectors and managers.

### 1.1. Classes of Sewage.

Classes of sewage include sanitary, commercial, industrial, agricultural, and surface runoff. The wastewater from residences and institutions, carrying body wastes, washing water, food preparation wastes, laundry wastes, and other waste products of normal living, are classed as domestic or sanitary sewage. Liquid-carried wastes from stores and service establishments serving the immediate community, termed commercial wastes, are included in the sanitary or domestic sewage category if their characteristics are similar to household flows. Wastes that result from an industrial process or the production or manufacture of goods are classed as industrial wastewater. Their flows and strengths are usually more varied, intense, and concentrated than those of sanitary sewage. Surface runoff, also known as storm flow or overland flow, is that portion of precipitation that runs rapidly over the ground surface to a defined channel. Precipitation absorbs gases and particulates from the atmosphere, dissolves and leaches materials from vegetation and soil, suspends matter from the land, washes spills and debris from urban streets and highways, and carries all these pollutants as wastes in its flow to a collection point (www.en.wikipedia.org).

### 1.2. What is a Sewage Spill?

Sewage spills occur when the wastewater being transported via underground pipes overflows through a manhole, cleanout, or broken pipe. Sewage spills cause health hazards, damage homes and businesses, and threaten the environment, local waterways, and beaches. Septic system failure can also result in exposure to sewage. Improper homeowner maintenance is the most common reason for septic system failure. If poorly maintained systems are not pumped out regularly, they have sludge (solid material) build up inside the septic tank. Sewage then flows into the absorption field, clogging it beyond repair. Heavy rains can saturate septic fields, causing systems to overflow and fail (www.hss.delaware.gov).

### 1.3. How can People be exposed to sewage?

People are exposed to sewage by hand-to-mouth contact during eating, drinking, and smoking or by wiping the face with contaminated hands or gloves. Exposure can also occur by skin contact, through cuts, scratches, or penetrating wounds, and from discarded hypodermic needles. Certain organisms can enter the body through the surfaces of the eyes, nose, and mouth, and they can be breathed in as dust, aerosol, or mist (www.hss.delaware.gov).

### 1.4. Hazards of Untreated Sewage.

Every year, hundreds of billions of gallons of untreated sewage flow into our rivers, lakes, and coastal waters. Unknowingly, many Americans and their loved ones risk serious illness when untreated sewage seeps into the water they use for recreation or drinking. The EPA (Environmental Protection Agency of the US) estimates that over 7 million people suffer from mild to moderate illnesses caused by untreated sewage every year. Another ½ million get seriously ill. However, the number of illnesses caused by raw sewage could be much higher than we think. Many people who get sick from untreated sewage are not aware of the cause of their illness and do not report it to their doctors or local health officials (www.hss.delaware.gov).

### 1.5. Pathogens.

Most illnesses that arise from contact with sewage are caused by pathogens, which are biological agents that cause disease or illness in a host. The most common pathogens in sewage are bacteria, parasites, and viruses. They cause a wide variety of acute illnesses, including diarrhea and infections. These illnesses can be violent and unpleasant but mostly pass after several days or weeks with no lasting effects. In some cases, however, pathogens can cause serious long-term illnesses or even death. Certain groups, such as children, the elderly, and those with a weakened immune system, are particularly vulnerable to these long-term effects. When the parasite cryptosporidium contaminated the drinking water supply in Milwaukee in 1993, 403,000 people became ill, and 70-100 people died, the vast majority of whom had been HIV-positive (www.hss.delaware.gov).

Furthermore, according to Lamb (www.ehow.com) and Green (www.ehow.com), pathogens are at the heart of most of the conditions that result from raw sewage. Sewage pathogens often include parasites, viruses, and bacteria, which cause diarrhea and infections. Though these conditions can be violent, they often pass within a few days or weeks without lasting effects; however, death can occur. Raw sewage is particularly dangerous to people who have weak immune systems, such as children and the elderly.

### 1.6. Toxic Algal Blooms.

In addition to pathogens, the high nutrient levels in untreated sewage can cause illness when they create algal blooms. Algal blooms are rapid increases in the population of phytoplankton algae, or single-celled plants that serve as an important food source for other organisms. The nutrients in sewage act as fertilizers and cause the number of algae to swell. Some algae are toxic to humans, and they can come in contact with them by eating shellfish or swimming or boating in contaminated water. Symptoms from exposure include memory loss, vomiting, diarrhea, abdominal pain, liver failure, respiratory paralysis, and coma. If an affected person does not receive proper medical attention, some toxins can be fatal (www.AmericanRivers.org).

Sewage and wastewater contain bacteria, fungi, parasites, and viruses that can cause intestinal, lung, and other infections. Bacteria may cause diarrhea, fever, cramps, and sometimes vomiting, headache, weakness, or loss of appetite. Some bacteria and diseases carried by sewage and wastewater are E. coli, shigellosis, typhoid fever, salmonella, and cholera. Fungi such as Aspergillus and other fungi often grow in compost. These can lead to allergic symptoms (such as runny nose) and sometimes can lead to lung infection or make asthma worse. If you have other health problems, you may be more likely to get sick from exposure to Aspergillus. Parasites, including Cryptosporidium and Giardia lamblia, may cause diarrhea, stomach cramps, and even nausea or a slight fever. Most people have no symptoms of roundworm (Ascariasis).

Roundworms cause coughing, trouble breathing, and/or pain in your belly and blocked intestines. Viruses such as Hepatitis A cause liver disease. Symptoms of Hepatitis A are feeling tired, having pain in your belly, being nauseous, having jaundice (yellow skin), having diarrhea, or not being hungry. The Centers for Disease Control and Prevention (CDC) says sewage workers are not at more risk of Hepatitis A infection than other workers. If many people in your community have Hepatitis A, your risk may be higher than usual.

Because of the lack of waste management facilities in some parts of the world, sewage can be dumped in locations that are inadequate for the protection of natural resources, such as freshwater locations, and inadequate for the protection of individuals from diseases. As improperly treated sewage contains a number of chemicals and germs harmful to the human body, allowing such waste to be dumped in locations vital for providing basic human needs will lead to long-term problems with serious illnesses. The fact that poorer countries are also often countries with higher temperatures and levels of humidity (conditions in which such diseases thrive) added an extra level of danger.

### 1.7. Leptospirosis.

One of the diseases that come from the improper treatment of sewage is Leptospirosis (known via its scientific name, *Leptospira icterohaemorrhegiae*). The disease is spread by parasitic worms and transferred to humans via contaminated water and rats. The disease causes a number of symptoms to an individual who contracts it, such as high fevers, severe loss of appetite, vomiting and nausea, severe head and muscle aches. These symptoms last for a period of between four to seven days.

### 1.8. Hepatitis A.

Another serious disease caused by the mistreatment of sewage is Hepatitis A. The ingestion of contaminated water mainly causes this disease and is potentially fatal in large enough quantities. Hepatitis A causes symptoms such as fever, abdominal pain, dark-colored urine, and jaundice and will often infect an individual several weeks before they have knowledge of potentially suffering from it. The disease has an incubation time of three to four weeks, meaning an individual can contract Hepatitis A and not suffer any symptoms until at least a month later.

### 1.9. Parasites.

Parasites are also a common consequence of the improper treatment of sewage (some of these parasites are Giardia and Cryptosporidium). These parasites are found in raw sewage and contaminated water, and the symptoms could last for years (fever, diarrhea, and severe stomach cramps). A difference between the diseases and the parasites is the fact that a minority of individuals don't suffer any negative symptoms from the contraction of parasites.

### 1.10. Gastroenteritis.

American Rivers (www.AmericanRivers.org) stated that approximately 1.5 million people suffer from gastroenteritis at beaches along two counties in California every year. The condition, one of the most common causes of raw sewage, results in inflammation of the intestines along the gastrointestinal tract. The result is diarrhea, cramping abdominal pain, nausea, and vomiting. People often refer to these symptoms as the "stomach flu," though influenza includes head and body aches, as well as respiratory symptoms. Gastroenteritis can also be caused by shellfish and other food-borne illnesses. Other illnesses include cholera, dysentery, and infectious hepatitis.

### 1.11. Wildlife.

High raw sewage levels can affect the ecosystem by killing fish and other wildlife. Algal growth can increase rapidly in areas with high raw sewage levels. Algae consume oxygen and deplete its abundance of fish. Areas, where high raw sewage is detected are the result of sewage lines that are improperly maintained or sewage that hasn't been treated correctly. This can cause closures at beaches and other water recreation areas, sometimes leading to a drop in tourism.

According to the Encyclopaedia Britannica (2014), malaria is a serious relapsing infection in humans, characterized by periodic attacks of chills and fever, anemia, splenomegaly (enlargement of the spleen), and often fatal complications. It is caused by one-celled parasites of the genus *Plasmodium* that are transmitted to humans by the bite of *Anopheles* mosquitoes. Malaria can occur in temperate regions, but it is most common in the tropics and subtropics. In many parts of sub-Saharan Africa, entire populations are infected more or less constantly. Malaria is also common in Central America, the northern half of South America, and in South and Southeast Asia. The disease also occurs in countries bordering on the Mediterranean, in the Middle East, and in East Asia. In Europe, North America, and the developed countries of East Asia, malaria is still encountered in travelers arriving or returning from affected tropical zones.

Malaria in humans is caused by five related protozoan (single-celled) parasites: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, *P. malariae*, and *P. knowlesi*. The most common worldwide is *P. vivax*. The deadliest is *P. falciparum*. In 2008, *P. knowlesi*, which was thought to infect primarily Old World monkeys and to occur only rarely in humans, was identified as a major cause of malaria in humans in Southeast Asia, accounting for as many as 70 percent of cases in some areas. *P. knowlesi* was found to be easily confused with *P. malariae* during microscopic examination, resulting in many cases being attributed to *P. malariae* when, in fact, they may have been caused by *P. knowlesi*.

*Plasmodium* parasites are spread by the bite of infected female *Anopheles* mosquitoes, which feed on human blood in order to nourish their own eggs. While taking its meal (usually between dusk and dawn), an infected mosquito injects immature forms of the parasite, called sporozoites, into the person's bloodstream. The blood carries the sporozoites to the liver, where they mature into forms known as schizonts. Over the next one to two weeks, each schizont multiplies into thousands of other forms known as merozoites. The merozoites break out of the liver and reenter the bloodstream, where they invade red blood cells, grow and divide further, and destroy the blood cells in the process. The interval between invasion of a blood cell and rupture of that cell by the next generation of merozoites is about 48 hours for *P. falciparum*, *P. vivax*, and *P. ovale*. In *P. malariae,* the cycle is 72 hours long. *P. knowlesi* has the shortest life cycle—24 hours—of the known human *Plasmodium* pathogens, and thus, parasites rupture daily from infected blood cells.

Most merozoites reproduce asexually—that is, by making identical copies of themselves rather than by mixing the genetic material of their parents. A few, however, develop into a sexual stage known as a gametocyte. These will mate only when they enter the gut of another mosquito that bites the infected person. Mating between gametocytes produces embryonic forms called ookinetes; these embed themselves in the mosquito's gut, where they mature after 9 to 14 days into oocysts, which in turn break open and release thousands of sporozoites that migrate to the insect's salivary glands, ready to infect the next person in the cycle.

Typically, victims who are bitten by malaria-carrying mosquitoes experience no symptoms until 10 to 28 days after infection. The first clinical signs may be any combination of chills, fever, headache, muscle ache, nausea, vomiting, diarrhea, and abdominal cramps. Chills and fever occur in periodic attacks; these last 4 to 10 hours and consist first of a stage of shaking and chills, then a stage of fever and severe headache, and finally a stage of profuse sweating during which the temperature drops back to normal. Between attacks, the temperature may be normal or below normal. The classic attack cycles, recurring at intervals of 48 hours (in so-called tertian malaria) or 72 hours (quartan malaria), coincide with the synchronized release of each new generation of merozoites into the bloodstream. Often, however, a victim may be infected with different species of parasites at the same time or may have different generations of the same species being released out of synchrony—in which case the classic two- or three-day pattern may be replaced by more frequent rigors of chills, fever, and sweating. The parasites continue to multiply—unless the victim is treated with appropriate drugs or dies in the interim.

Besides attacks, persons with malaria commonly have anemia (owing to the destruction of red blood cells by the parasites), enlargement of the spleen (the organ responsible for ridding the body of degenerate red blood cells), and general weakness and debility. Infections due to *P. falciparum* are by far the most dangerous. Victims of this “malignant tertian” form of the disease may deteriorate rapidly from mild symptoms to coma and death unless they are diagnosed and treated promptly and properly. The greater virulence of *P. falciparum* is associated with its tendency to infect a large proportion of the red blood cells; patients infected with that species will exhibit ten times the number of parasites per cubic millimeter of blood than patients infected with the other three malaria species. In addition, red blood cells infected with *P. falciparum* have a special tendency to adhere to the walls of the tiniest blood vessels or capillaries. This results in obstruction of the blood flow in various organs, but the consequences are gravest when capillaries in the brain are affected, as they often are. It is this latter complication—known as cerebral malaria and manifested by confusion, convulsions, and coma—that frequently kills victims of *P. falciparum* malaria. Several strains of *P. falciparum* have developed that are resistant to some of the drugs used to treat or prevent malaria.

Infections of *P. vivax* and *P. ovale* differ from the other two types of malaria in that some of the sporozoites may remain dormant in the liver in a “hypnozoite” stage for months or even years before emerging to attack red blood cells and cause a relapse of the disease.

The Geographic Information System (GIS) provides an interactive platform by which maps that have been created of geospatial attributes can be queried in sort of user-friendly interfaces such that a “deep-mine” of acquired geospatial data can be readily processed and the result displayed in rapid relatable formats that constitutes the basis of a veritable audit mechanism. Jonah *et al.* (2011), Jonah and Jimoh (2013), Jonah and Ayofe (2014), Jonah and Saidu (2018), and Jonah and Sunday (2021) have employed this audit mechanism characteristic of the GIS in their works on urban built-up landmarks, site-specific topographic, natural-material economic-resource, raw sewage, and air pollution inquiries.

A GIS is a computer system for performing geographical analysis. GIS has four interactive components: an input subsystem for converting into digital form (digitizing) maps and other spatial data, a storage and retrieval subsystem, an analysis subsystem, and an output subsystem for producing maps, tables, and answers to geographic queries. GIS is frequently used by environmental and urban planners, marketing researchers, retail site analysts, water resource specialists, and other professionals whose work relies on maps. GIS evolved in part from the work of cartographers, who produce two types of maps: general-purpose maps, which contain many different themes, and thematic maps, which focus on a single theme such as soil, vegetation, zoning, population density, or roads. These thematic maps are the backbone of the GIS because they provide a method of storing large quantities of fairly specific thematic content that can later be compared.

## 2. METHOD

### 2.1 Study Area Segmentation and Pre-Survey.

At the outset, Minna township built-up areas, shown in Figure 1, were segmented into five sectors, namely Greater Bosso, Minna Central, Greater Maitumbi, Tunga, and Greater Chanchaga. Subsequently, the pre-survey stage, whence the survey party visited random segment locations for site familiarisation and testing of the hand-held Geographic Information System unit especially, was initiated.

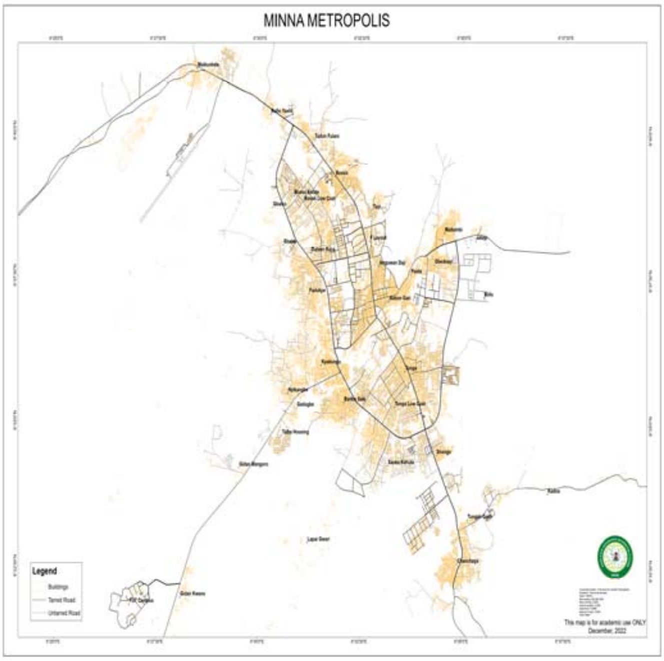

***Figure 1.** Map of Minna township*

### 2.2. Principal Survey Procedures.

Upon the familiarisation trips to the broader survey area, the main exercise kicked in. Crew members investigate every acre of assigned sectors for locations where sewage water freely flows out of households into the neighborhood, forming slow-moving puddles. At such a location, geographic information coordinates are taken along with the date of survey, time of the survey, weather at the time of the survey, name of recorder or data specialist, and information about the defaulter householder (where this is volunteered). The survey party also takes photographs of the point of interest. This process is repeated for as many points as can be accessed by the data specialists. All this germane information is recorded on a purpose-specific datasheet.

## 3. RESULTS AND DISCUSSION

### 3.1 Analyses of Data

### 3.1.1 Importing Latitude and Longitude Information at Each Survey Point into ArcGIS®10.8.

From each data sheet corresponding to a distinct raw sewage pollution point, latitude and longitude (x-y) information was extracted and imported into the ArcGIS®10.8 software. Next, the World Geodetic System (WGS 1984) platform was chosen as the default coordinate system for the x-y information.

### 3.1.2 Acquisition of the Minna Township Built-up and Settlement Shapefiles.

The Minna township built-up and settlement shapefiles were duly acquired and imported into the ArcGIS®10.8 software. By merging the two distinct shapefiles, the required substrate of major and minor roads and settlements was activated, thus defining a collage of the Minna township map.

### 3.1.3 Creation of the Minna Raw Sewage Pollution Layer.

It is necessary to create polygons for locations with identified raw sewage pollution menace so as to separate these regions from other unpolluted zones. For the five sectors, distinct polygons were also created to segment the respective sub-study areas. This means that the road networks and settlements in these sectors are emphasized on the collaged Minna township map. Each georeferenced location is consequently highlighted on its true placement point in the respective sub-study areas. Figures 2 to 6 show the raw sewage pollution layers on the Minna GIS map for the different sectors of the town.

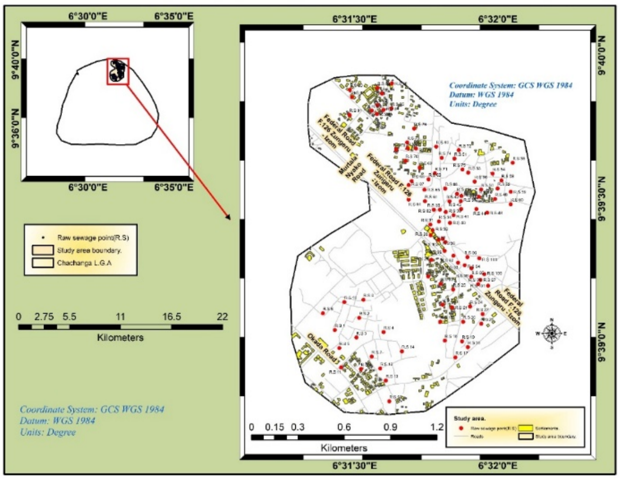

***Figure 2.** The raw sewage pollution layer for Greater Bosso shows more sanitation default zones at the central to the north-northcentral portions*

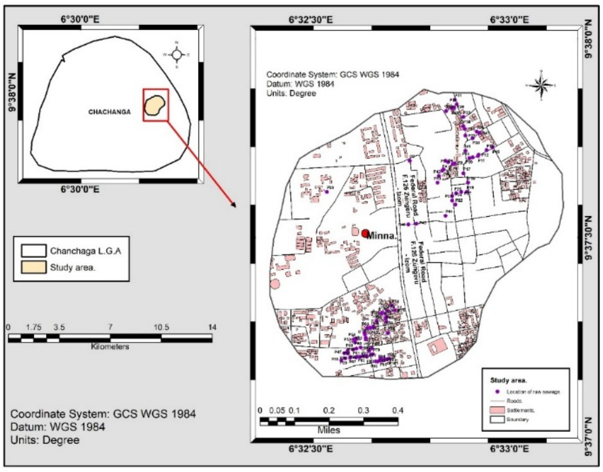

***Figure 3.*** Composite raw sewage pollution layer for Minna Central showing zones of obvious mosquito breeding sites at the southwest and northeast

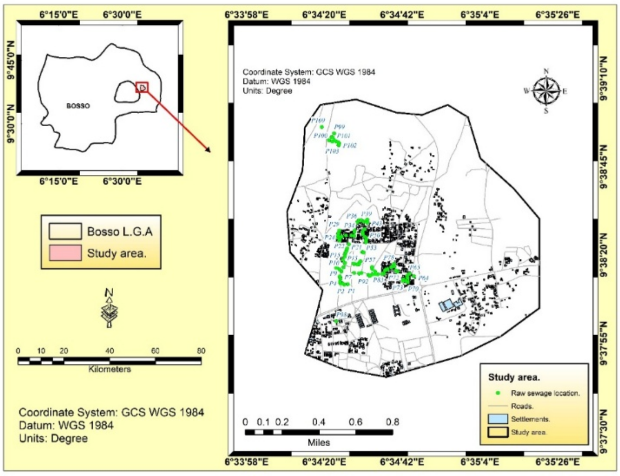

***Figure 4.*** Composite raw sewage pollution layer for Greater Maitumbi showing preponderance of slum settlements at the central to the northwest portions

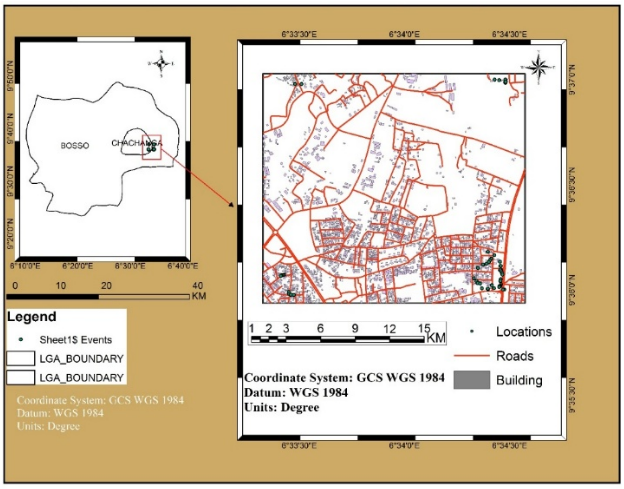

***Figure 5***. Composite raw sewage pollution layer for Tunga with no defined slum-settlement clusters or mosquito-breeding locations except at a tiny segment of the southeast portion of the neighborhood as well as at the extreme southwest

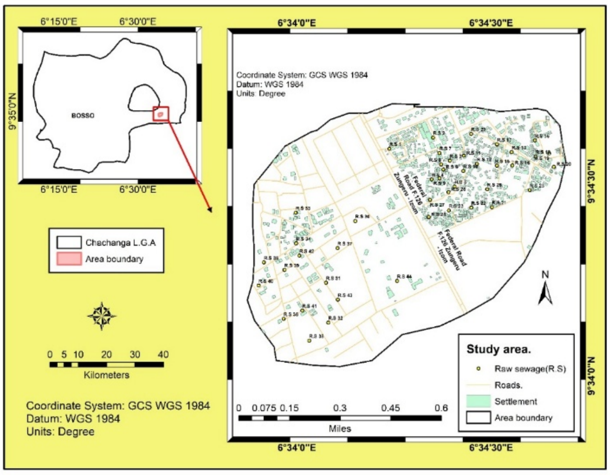

***Figure 6.*** The composite raw sewage pollution layer for Greater Chanchaga indicates that poor housing settlements that favor mosquito-breeding locations are concentrated to the northeast and southwest of the federal highway bisecting this neighborhood

### 3.2 Discussion

The composite raw sewage pollution maps for the neighborhoods of Greater Bosso, Minna Central, Greater Maitumbi, Tunga, and Greater Chanchaga form the contiguous collaged map of Minna's built-up township. Representative dots at their true latitude-longitude positions on each sectored polygon area have been colored-coded to represent a raw sewage pollution point. However, the use of different color schemes for the different sectors was just a mere aesthetic excursion. Figure 2 indicates that more than 50% of the households visited are at default of sewage sanitation. The southern one-half of the Greater Bosso neighborhood, indicating fewer clusters, is the portion where very influential government functionaries and businessmen have built their dwellings in spite of cultural norms.

The information gleaned from Figure 3 indicates less than 25% raw sewage pollution regime for the Minna Central neighborhood.

The fact known to residents of Minna is that the proportion of green-clustered dots for the core Greater Maitumbi sub-study area of Figure 4 should be 95%-plus. The core built-up neighborhood is one large expanse of slum-infested portion of town. Alas, investigations for this study were limited to tiny portions of the northwest and the west-central neighborhoods of Greater Maitumbi, where the proportion of households at the default of sewage sanitation was over 90%. Wide expanses of undeveloped bushlands ring off the core Greater Maitumbi sub-study area at the heart of Minna.

In the Tunga neighborhood, heavily built-up in the southern sector, as indicated in Figure 5, survey density does not correspond to housing density (this was due to survey resources constraints), but for the locations visited at the built-up zones of the northwest, northeast, southwest, and southeast, green-dot clusters overlap in regimes or patterns that will be nightmarish for town planners. The northern sector of the Tunga neighborhood is characterized by open spaces of undeveloped fields with wild vegetation growing there.

The densely built-up northeast zone characterizes the Greater Chanchaga neighborhood of Figure 6 and the comparatively spaced-out southwest zone, conveniently separated by the arterial F126 highway that traverses Minna town. Clusters of yellow dots in higher proportion are the norm for the northeast zone vis-à-vis the southwest zone.

## 4. CONCLUSIONS

Greater Bosso has its share of raw sewage pollution spots that form clusters in poor and low-income neighborhoods. Overall, economic status is a very important factor governing household sewage piping and proper collection in purpose-built cesspits. However, there are, regrettably, relatively affluent homes that still elect to pipe wastewater through orifices bored through the bottom of their brick fence. In Figure 2, the red clusters at the northeast are the slum settlement of Angwan Biri and its outlying neighborhood, whilst those traversing the F126 are the contiguous slum settlements of Hayin Gwari and Central Bosso built-up areas. The scattered red dots in the southeast zone correspond to the relatively well-planned Okada Road neighborhood. Stagnant pools of wastewater that correlate with the red dots in Figure 2 are the media that encourage mosquitoes to breed perennially in this neighborhood. It is no surprise that endemic malarial infestations are commonplace in the Angwan Biri, Hayin Gwari, and Central Bosso built-up areas. The Bosso Campus of the Federal University of Technology, Minna, is actually located in the Central Bosso sector.

The contiguous low-income slum settlements of Limawa and Makera are recognized in Figure 3 by the clusters of purple dots at the south end of the sector, whilst the clusters at the northeast are the densely-populated, unplanned Angwan Sarki-Angwan Daji sectors. There cannot be much surprise here because the clusters observed here correspond to frontier settlements of Minna township from over 80 years ago. It is within the Minna Central neighborhood that the Government Reservation Area (GRA) neighborhood is located at the northwest and where retired army generals' (including two former heads of state) homes fuse with government offices and the Central Bank's offices plus other commercial banks' operation offices at the east-central portion. The northwest and southeast portions of the Minna Central neighborhood are the "cleanest" habitable built-up areas because of the absence of sewage sludge that encourages mosquitoes and other vermin to breed. This situation sharply contrasts those of the Limawa, Makera, and Angwan Sarki-Angwan Daji sectors.

The predominance of clusters of green dots in Figure 4 for Greater Maitumbi indicates obvious slum settlements. Were available resources to permit a full-scale house-to-house survey, there is no doubt Figure 4 will be one green-dot clustered map.

Obviously, the slum-dwelling conclusion associated with dot clusters can be made for the northwest, northeast, southwest, and southeast portions of Figure 5. These relatively small segments forming a veritable disconnected "ring" over the wider Tunga neighborhood will lead to the obvious subjective conclusion that Inner Tunga suffers raw sewage sanitation default. Nonetheless, a purpose-specific study must be conducted in this regard. The Tunga sector is one of two "old town" neighborhoods (the other being Minna Central) of Minna from over 80 years ago, and not having a built-up segment designated for GRA, it is a veritable sewage-sludge-cum-mosquito-breeding built-up neighborhood.

Yellow-dot spread corresponds to residential densities in the two zones of interest in the Greater Chanchaga sector of Figure 6, and this pattern appears to be the norm. Clustered, poorly-spaced homesteads are the default of raw sewage sanitation, and thus, these homesteads provide a convenient breeding ground for mosquitoes, thereby engendering endemic malarial infestation.

## 5. DECLARATIONS

### 5.1 Study Limitations

From the outset, the projected expense to be incurred by a study of this nature necessitated its execution in a format of a suite of collaborators covering different assigned portions of Minna town. A good enough coverage for academic purposes can be achieved if resources are pooled in this format. If external sources of funding and collaboration had been secured for this study, then a time-independent investigation observation would have also been adopted.

### 5.2 Acknowledgments

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### 5.3 Funding Source

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### 5.4 Competing Interests

The authors declare that there exists no conflict of interest whatsoever arising from the preparation of this manuscript for publication with any other competing interests, whether they be of the authors' or of second parties and third parties thereof. The data employed in the enunciation of the textual material herein are original, having been duly acquired by the authors as part of the annual undergraduate schedule of project supervision here at the Federal University of Technology, Minna, Nigeria. This body of data field, duly archived for validation and reference purposes, are available for integrity checks anytime.

### 5.5 Open Source

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